Can short-term hydrogeological experiments predict the long-term behavior of subsurface reservoirs?

An example from shallow geothermy

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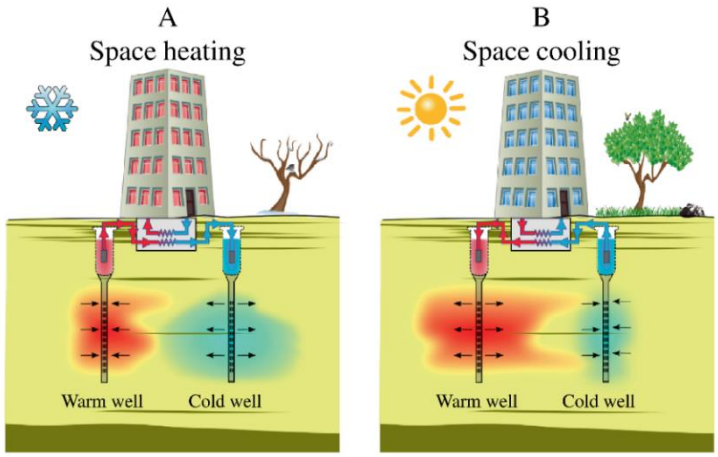
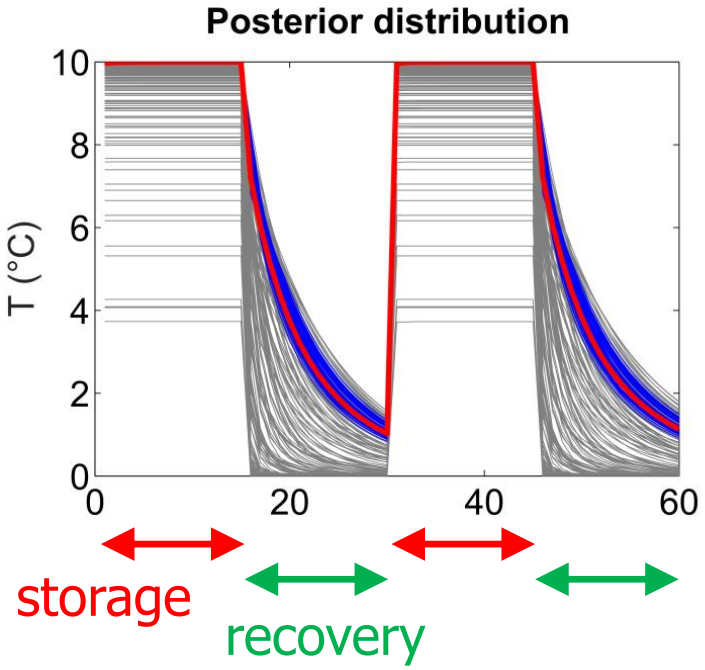
In ATES design, storage capacity is the prediction



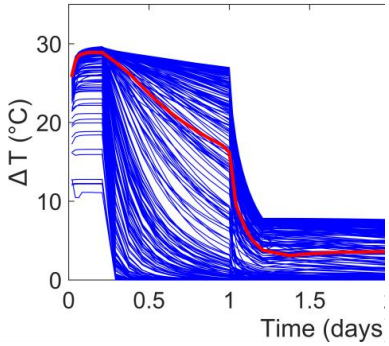
Modified after Bonte (2013)

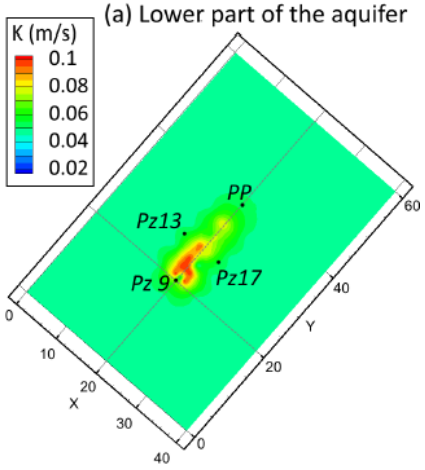
$h = T(t)$

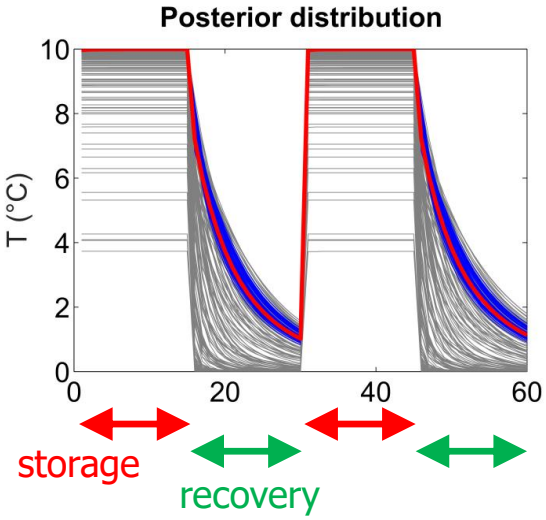


To obtain this prediction, the classical way is the deterministic approach

Data ⟶ **Model** ⟶ **Prediction**





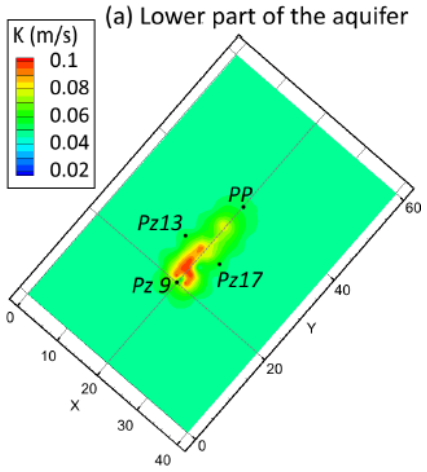


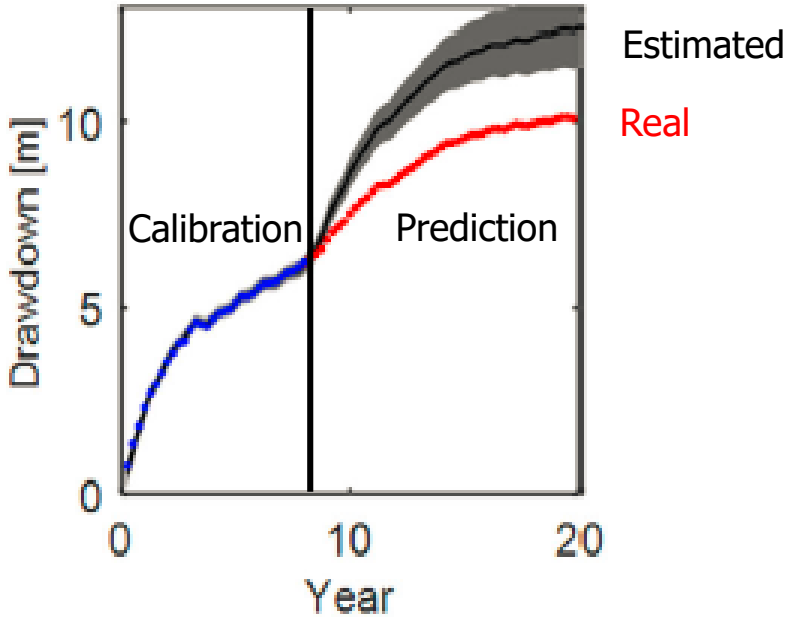
$h = T(t)$

Is this approach satisfactory?

Models often fail to predict within the correct range

Model → **Prediction**





We have to consider prior uncertainty!

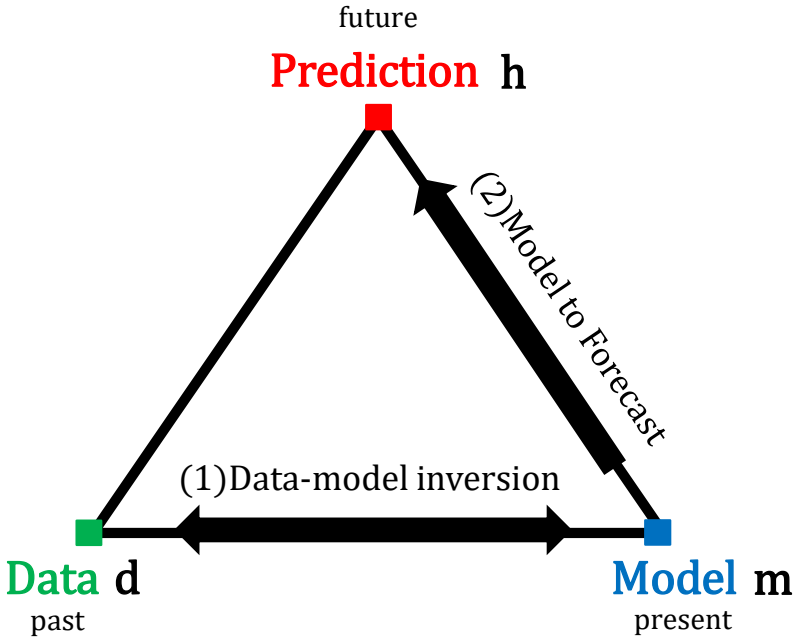
Introduction

The BEL framework

Its validation

Answering the question

A change of paradigm is necessary



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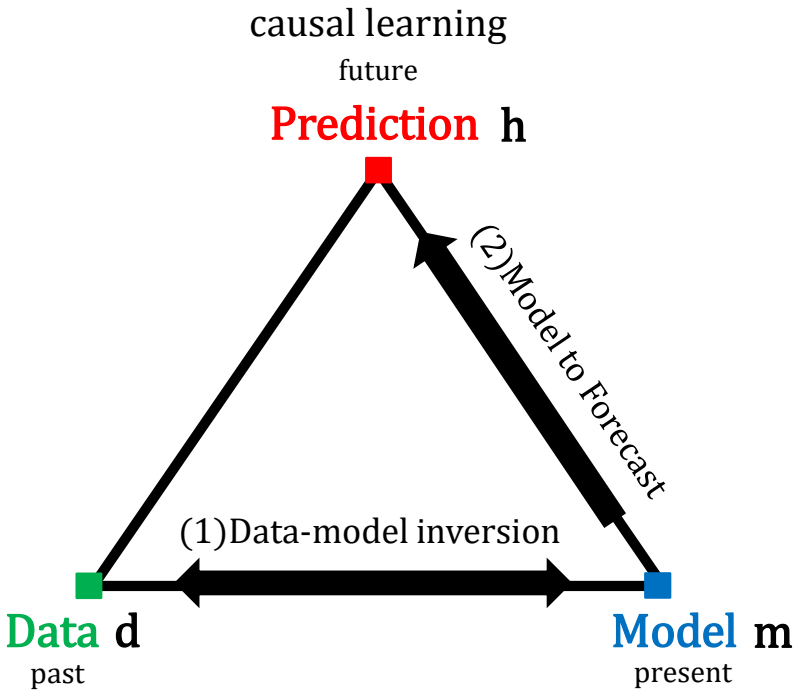
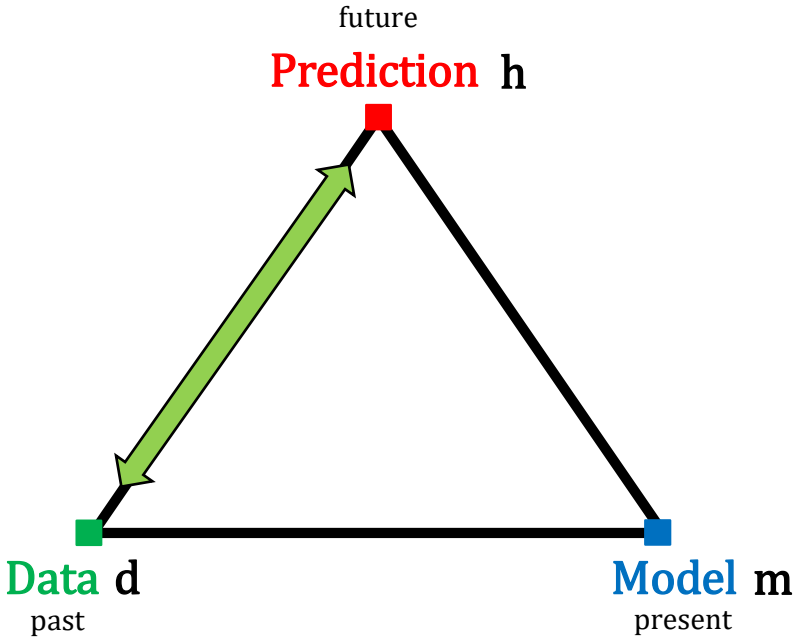
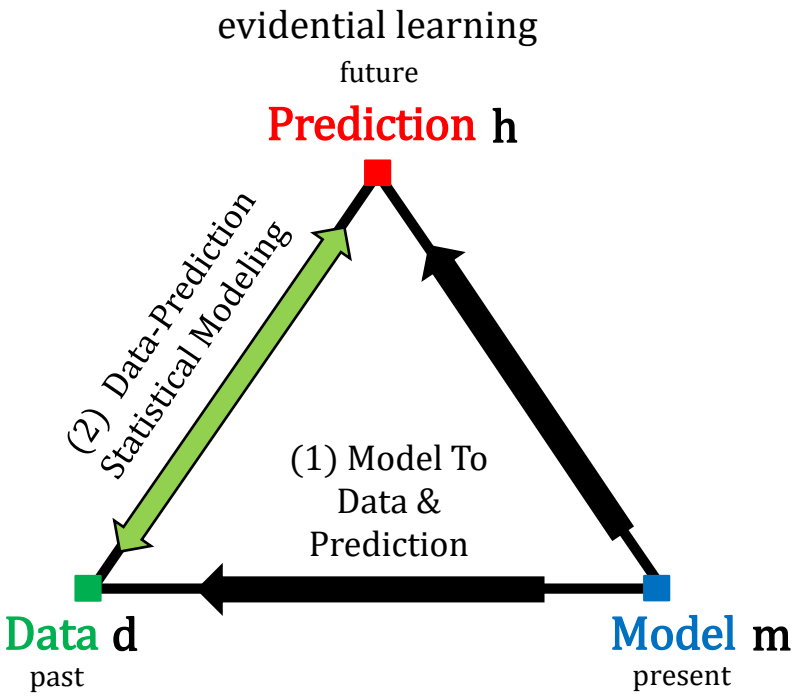


High risk of modeling paralysis

What if we could find a direct relationship between the past and the future?



Bayesian Evidential Learning (BEL)



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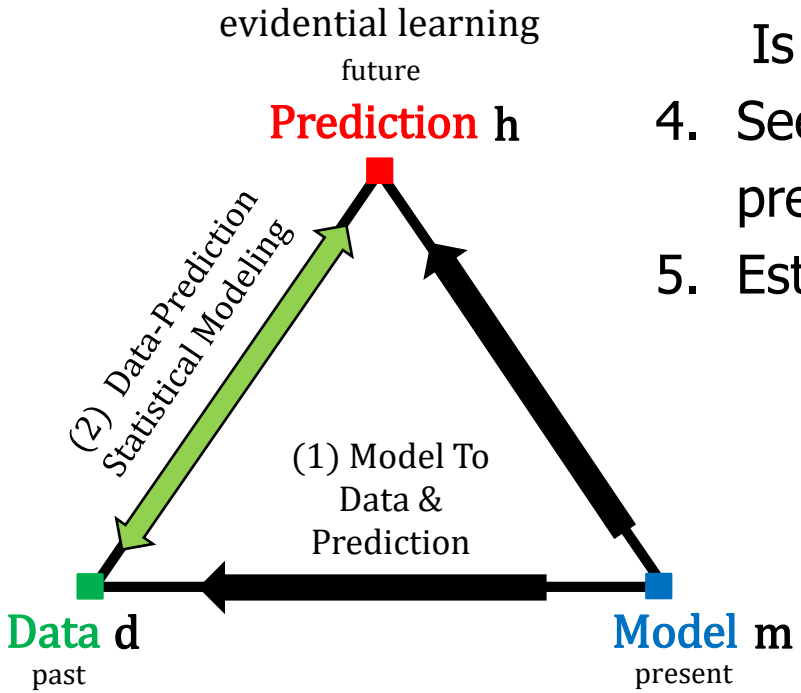

1. Generate realistic models (not calibrated) based on our geological knowledge
2. Simulate our data sets and our prediction
3. Assess the sensitivity of both
   Is the data informative?
4. Seek a direct relationship between data and prediction
5. Estimate the real prediction with field data

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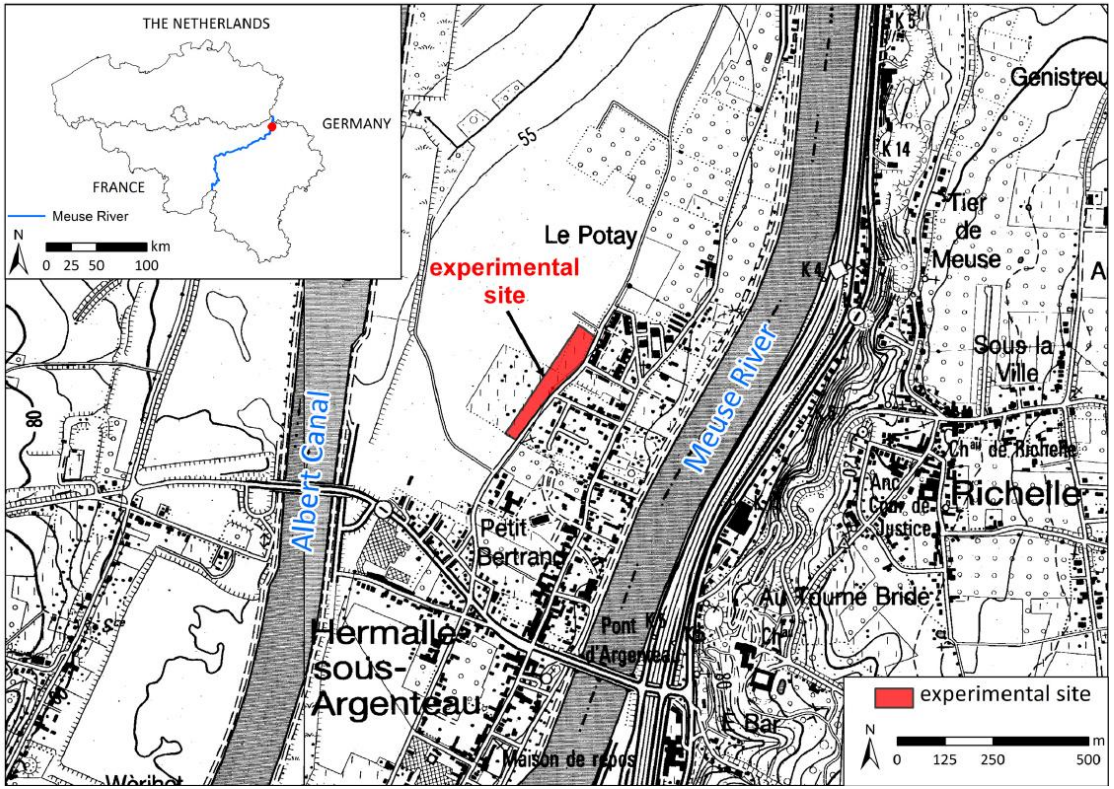
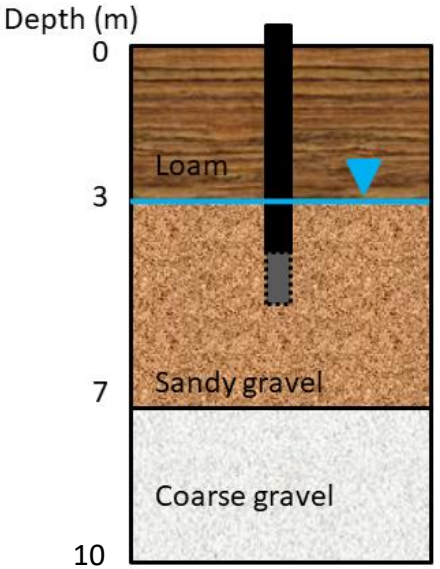
Prior information
HssA site

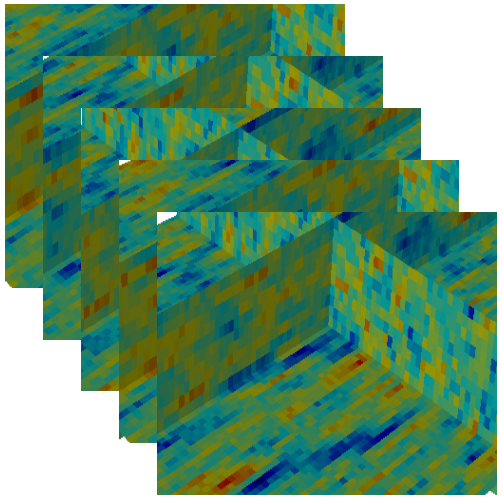




1. Generating Surrogate models

What do we know, what do we ignore ?

Models



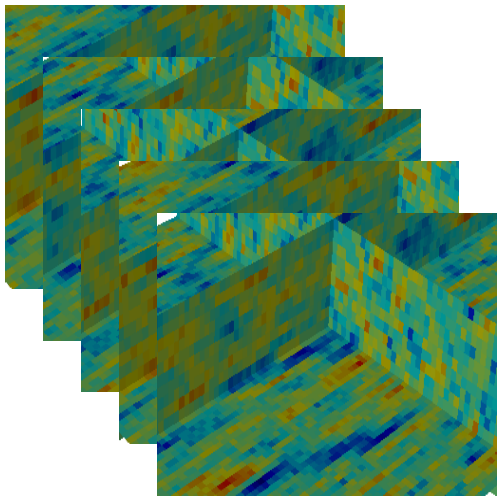
500 realizations =
surrogate models

Parameters	Status	Value
Mean of $\log_{10}$ K (m/s)	Variable	U[-4 -1]
Variance $\log_{10}$ K (m/s)	Variable	U[0.05 1.5]
Range (m)	Variable	U[1 10]
Anisotropy ratio	Variable	U[0.5 10]
Orientation	Variable	U[-π/4 -π/4]
Porosity	Variable	U[0.05 0.40]
Gradient (%)	Variable	U[0 0.167]
Other parameters	Fixed	

2. Simulate **d** and **h**

prior data and prediction variables

Models



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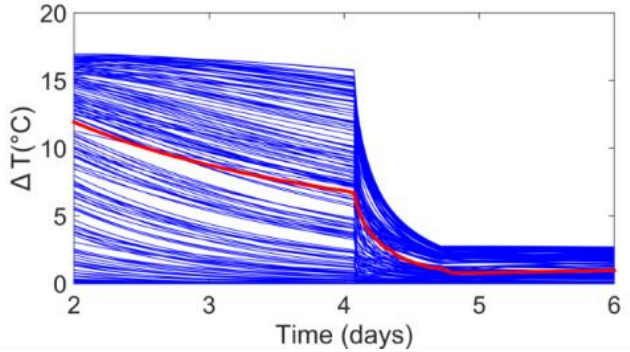
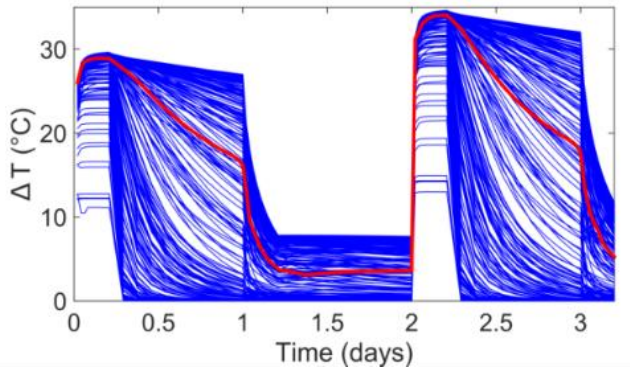


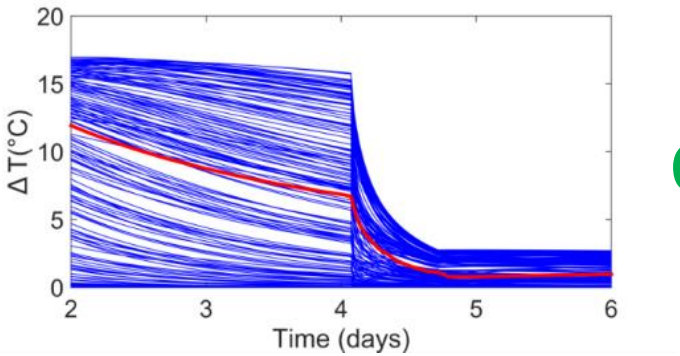
d



h

3. Global sensitivity analysis

Is the data informative for the prediction?



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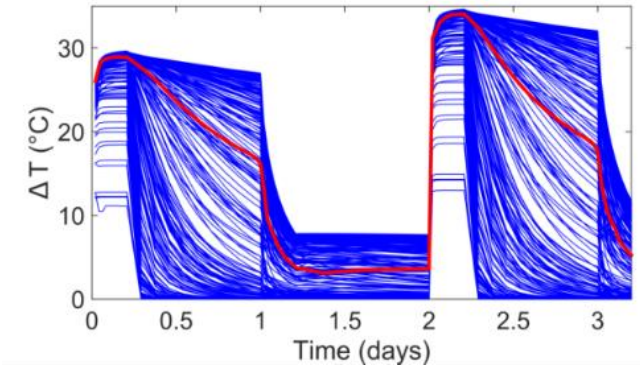

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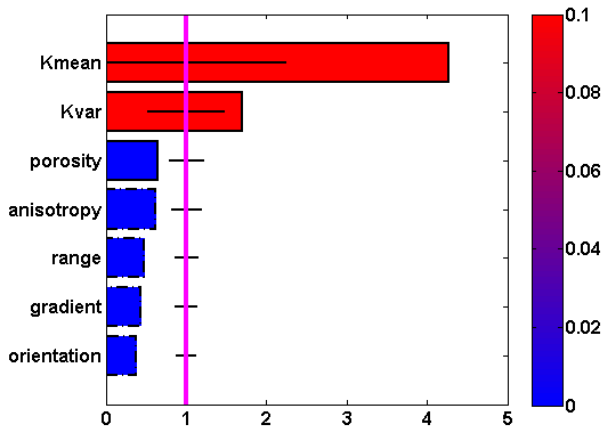
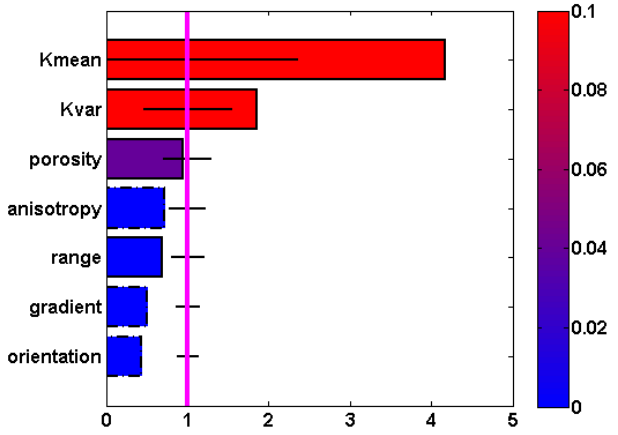
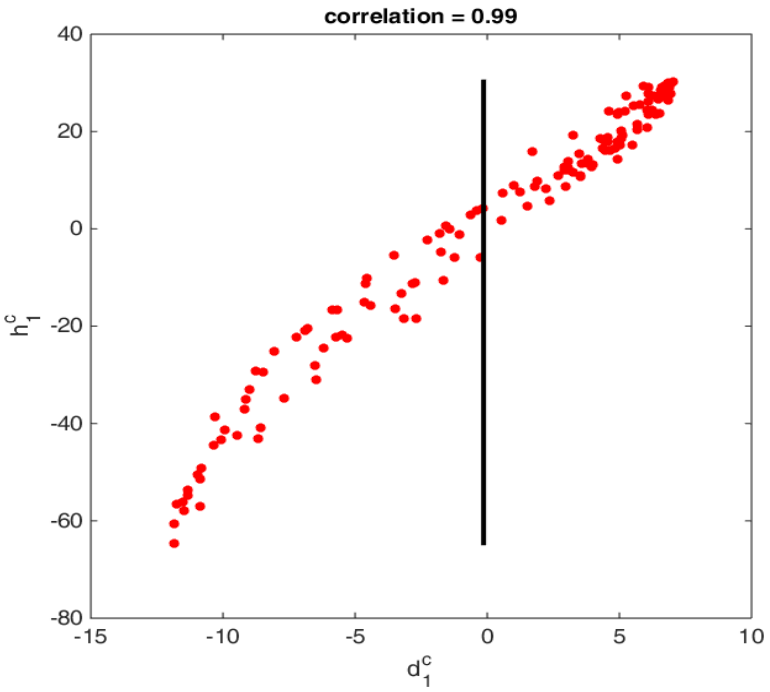
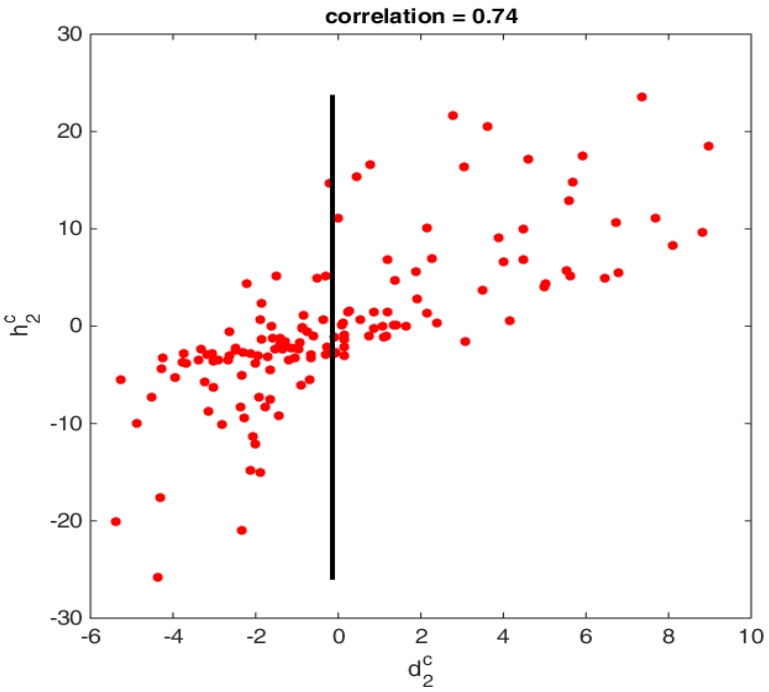




4. Any statistical relationship?

Dimension reduction with PCA and linearization with CCA

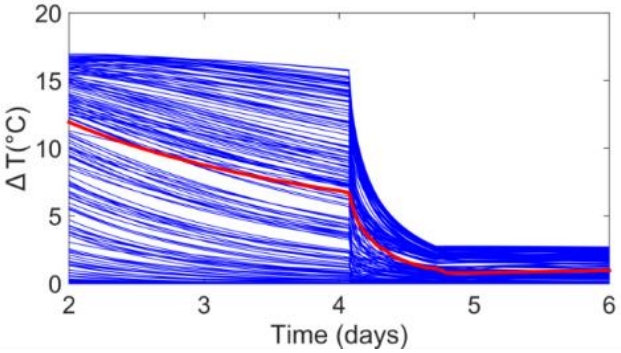




● models from the prior | field observations

5. Posterior distribution

Predictions associated with posterior uncertainty



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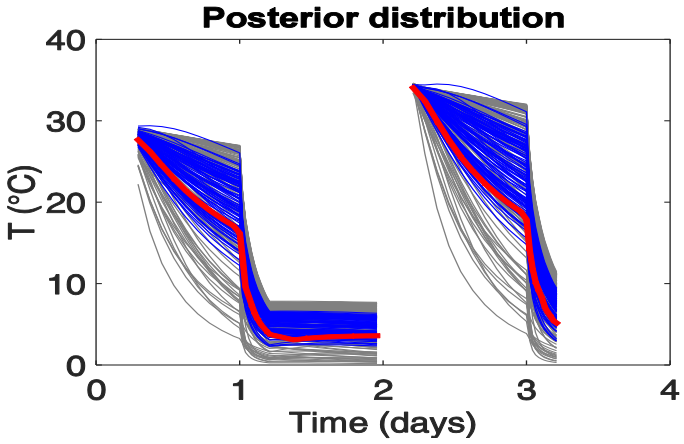
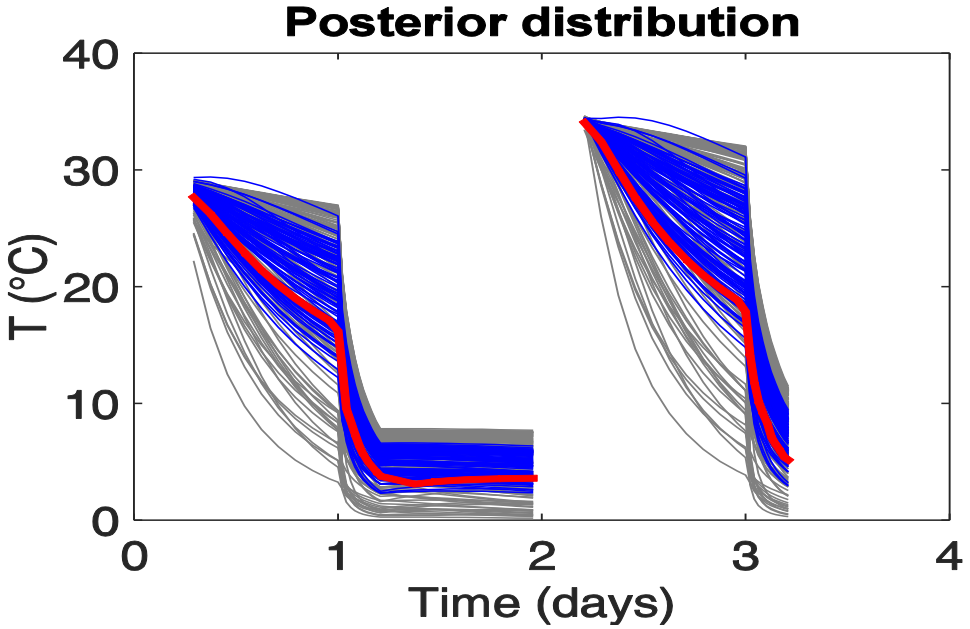


Adding real data

(red line)

We used one test to predict the second one

The reality lies in the posterior distribution → validation!



BEL shows you at least the good direction

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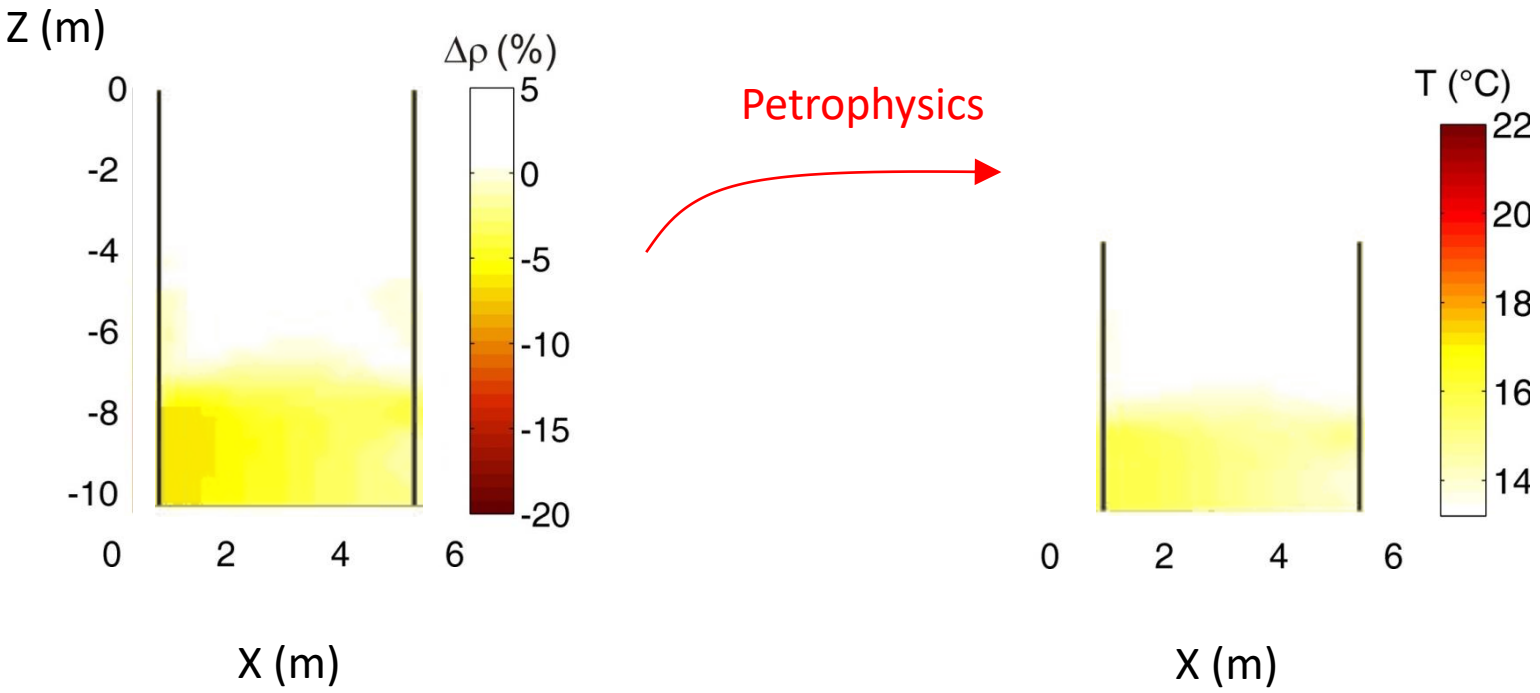
Answering the question

Can short-term hydrogeological experiments predict the long-term behavior of subsurface reservoirs?

Let’s find out with two types of data

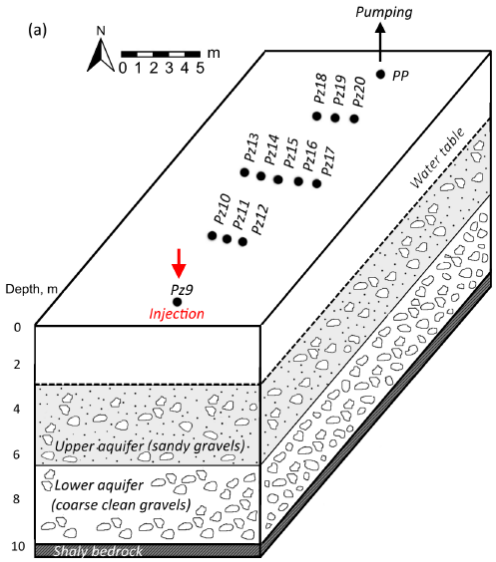
Time-lapse ERT

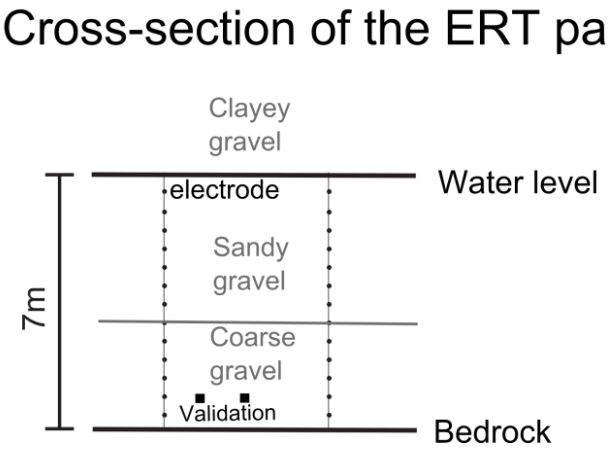
ERT is Electrical Resistivity Tomography and can follow T



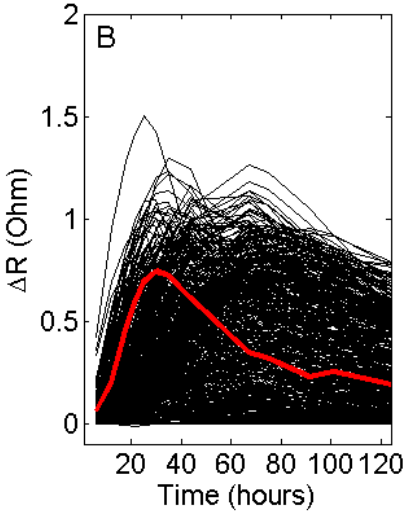
Time-lapse ERT

The set-up



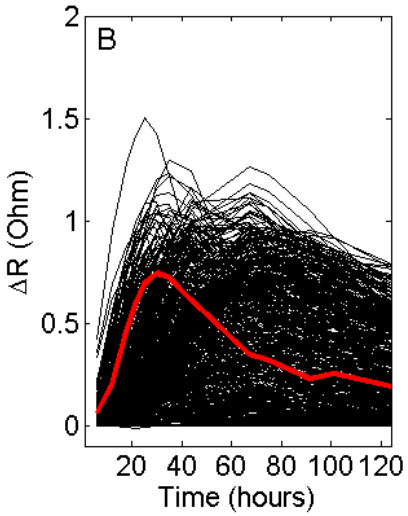


The data



Time-lapse ERT is clearly informative!

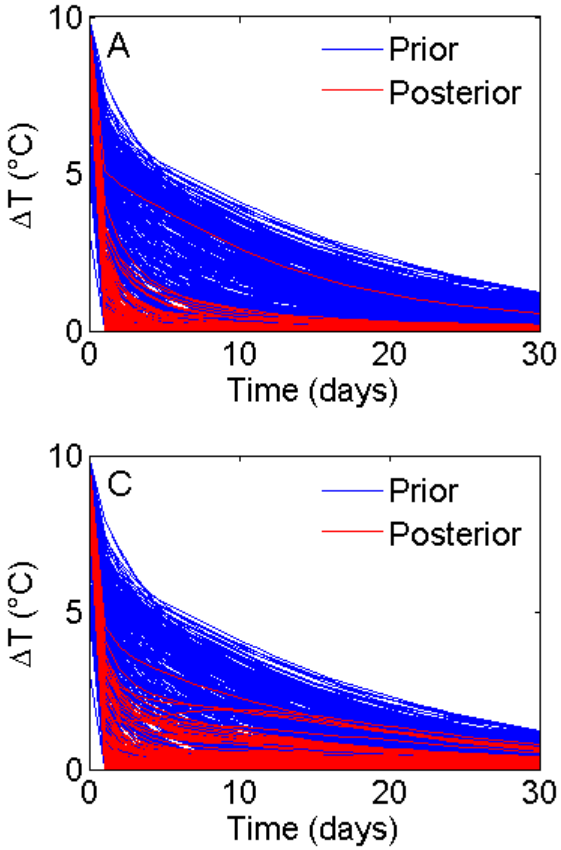
d



1st day of the test

The whole test (5 days)

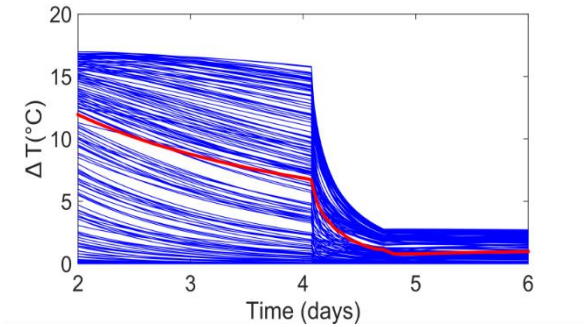
h

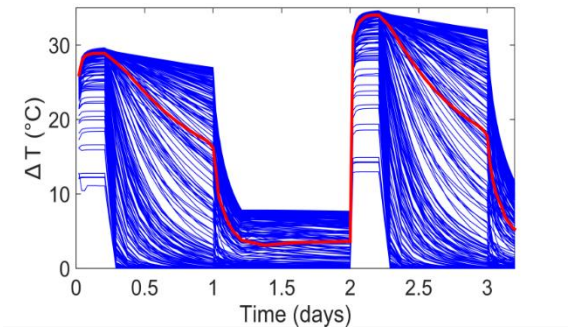


1 day of data is informative enough!

Simple or short push/pull tests are as informative as more complex ones

d





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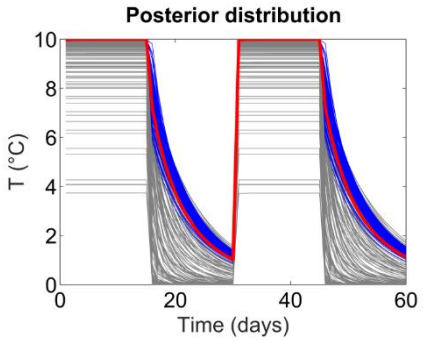

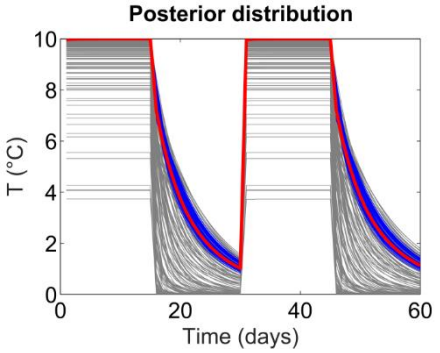

Can short-term hydrogeological experiments predict the long-term behavior of subsurface reservoirs?

Can short-term hydrogeological experiments predict the long-term behavior of subsurface reservoirs?

Yes, it can!

Can short-term hydrogeological experiments predict the long-term behavior of subsurface reservoirs?

Yes, it can!

And BEL allows to quantify that in advance

Any questions?

Groundwater Quality 2019

The next IAHS conference on Groundwater Quality (**GQ 2019**) will be held in Liège (Belgium) on 9-12 September 2019 !

With the support of IAH, NICOLE, UK CL:AIRE and EU H2020 ITN iNSPIRATION

More information : **aimontefiore.org/GQ2019**

Contact: c.dizier@aim-association.org – serge.brouyere@uliege.be

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